Pillar Neutron Detector Fabrication

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The goal of this project is to implement a set of process recipes for the fabrication of the “pillar detector” device that identifies special nuclear materials by detection of thermal neutrons. This new device can meet the demands of high efficiency and fieldability while maintaining a small device footprint, enabling covert applications.

Relevance to LLNL Mission

Thermal neutron detectors are used to determine the presence of special nuclear materials. This falls under the Laboratory’s mission area of global security.

FY2007 Accomplishments and Results

The work carried out in FY2007 was focused on the processing of the pillar detector device. The process flow is shown in Fig. 1. We are using contact photolithography to define 2-µm-diameter pillars with 2-µm separation. Next, plasma etching is used to etch the pillars with varying etch depth. The pillars are then filled with boron-10. This boron-10 material is responsible for converting the neutrons to alpha and lithium particles.

The next step in this process is the planarization of the boron. This is a major task of this project. We have evaluated

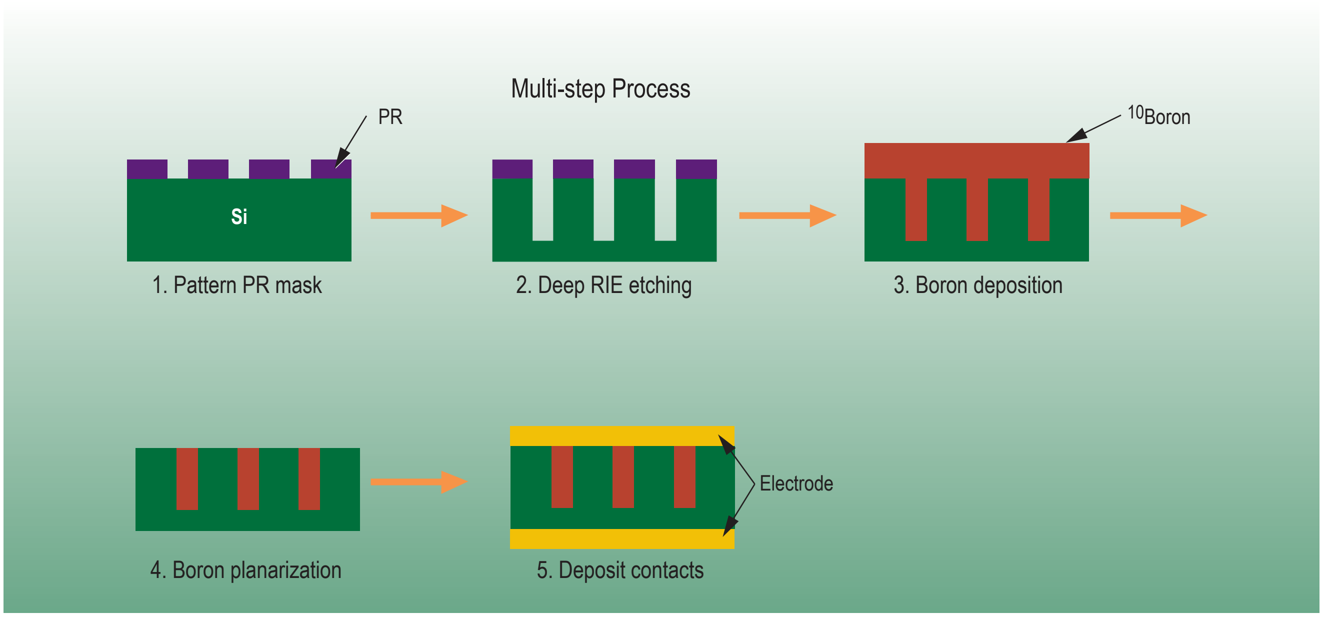

Figure 1. Multi-step fabrication process for pillar detector.

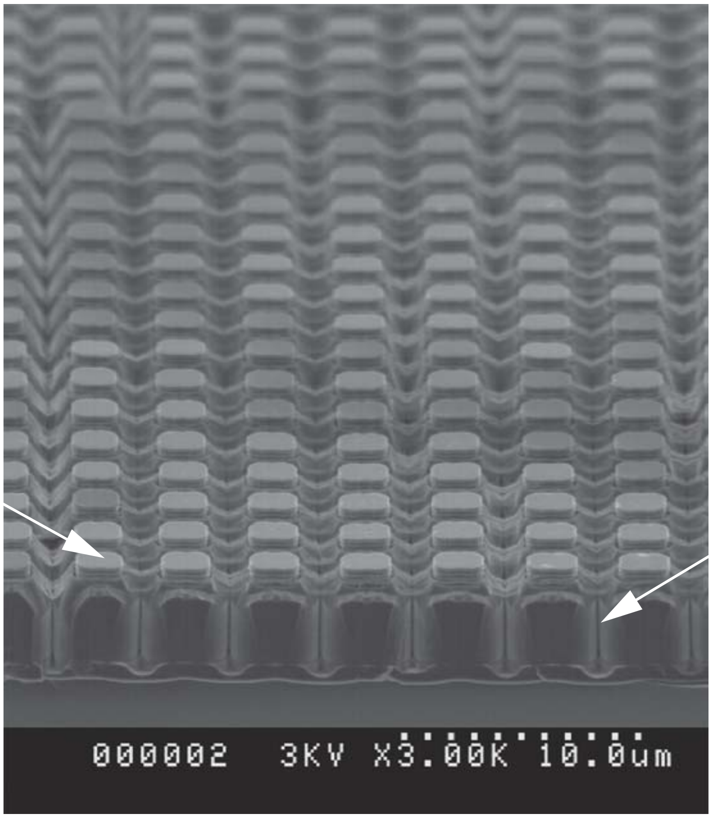

Figure 2. Pillar array after $CF_4/H_2/O_2$ plasma etch-back process.

chemical mechanical polishing, wet etching and plasma processing to determine an appropriate recipe for this planarization. Plasma etching using a mixed gas composition of $CF_4/O_2/H_2$ gave the best results in terms of a fast etch rate of 0.2 μm/min while maintaining a smooth and planar surface.

Each component of the reaction gas mixture is required for the fast etch rate. The O_2 removes the carbon layer that forms on the surface. If the carbon layer is not removed the etch process will terminate. The CF_4 and H_2 are both responsible for the chemical etching of the boron by reacting with the fluoride and hydrogen.

Figure 2 shows a representative pillar chip after the boron etch step. Once the device is planarized, electrical contacts can be placed on the top and bottom of the device. Aluminum is used for both the top and bottom electrode. For the top electrode, a higher pressure (25 mT vs. 6 mT) sputter deposition is required to coat the uneven topography. In packaging the devices, we used conductive silver epoxy to attach the pillar chip to the package and simultaneously make electrical connection to the bottom contact of the pillar chip. Wire bonding was then used to connect the top electrode to the package leads.